

The high quality yarns – the first condition for quality textiles

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Abstract. This paper is part of a more extensive study that aims at optimizing the technologies of manufacturing 100% cotton yarns and cotton blended with chemical fibers, polyester, both using classic spinning technologies, with rings, and unconventional technologies, open-end with rotor.

The problems, difficulties that occur always in the processing of cotton fibers are those related to the unevenness of the yarns made. This unevenness or non-uniformity is natural considering the non-uniformity of the physico - mechanical characteristics of cotton fibers. These are natural fibers and physico-mechanical characteristics are dependent on a number of factors such as the number of sunny days, average temperature, the amount of precipitation, etc.

Starting from the characteristics of the fibers processed, it is necessary to find suitable technological parameters in order to use, to exploit the characteristics of the processed fiber.

As the optimization method, it has been chosen to use central rotatable programs with two independent variables. In the study were chosen the most important parameters for each machinery in the technological process, and as the dependent variable was chosen the unevenness of the breaking load of the made yarns.

The technological flow used includes the blow room line, cards, drawing frames, roving frames, spinning machines and unconventional spinning machines. For this paper we will approach the optimization of the technological parameters of blow room aggregate.

After the experiments we determined the characteristics of the yarns, we established the regression equation of the mathematical model and set the values for the independent variables for to the lowest value for the unevenness of the breaking load.

At the end of the study we made the yarns with the values set for the independent parameters and we found that the yarns made are of adequate quality, correlated with the physical-mechanical characteristics of the processed fibers.

1. Introduction

The worldwide intensive use of computing, design and research, storage of large volumes of data, creation of databases and computer simulation of numerous processes and phenomena, facilitate the production of new materials with superior quality and optimally from an economic point of view, to meet the needs of consumers.

Generally, textile raw materials and textile products are characterized by several properties and their values are influenced by a multitude of factors that determine their variation. Numerous measurements are carried out on raw materials, but the adoption of correct decisions based on quantitative information requires the application of appropriate statistical methods.



Besides, technological adjustments made or the adoption of technological parameters for processing, must lead to manufacturing of semi-finished products and products with improved performances to satisfy the requirements imposed by their end use.

The method of successive variation of a single variable to asset the optimum interval consumes a lot of experimentation time. Additionally, opposite to the intended purpose, it may not recognize the global optimum due to the interaction of two or more independent variables. These interactions can exert a double influence, in locating the global optimum and in interpreting the physical meaning of the results. Interactions can also be multiple, thus a plan for their detection is mandatory needed.

This study present a series of contributions on the optimization of spinning technologies of manufacturing 100% cotton yarns and cotton blended with chemical fibers, polyester, both using classic spinning technologies, with rings, and unconventional technologies, open-end with rotor. Aim of experimental part was to produce yarns with linear density of 25 tex (Nm 40), end use weft from 100% cotton and cotton blended with chemical fibres.

In textile domain, particularly spinning, experimental design and optimization are tools currently used to analyze different types of problems that emerge within yarn manufacturing, related to the unevenness of the yarns [1, 2, 3].

2. Materials and methods

2.1. Experimental design

In this work, as optimization method, we adopted a central rotatable program with two independent variables [4, 5, 6]. In any experimental method several variables or factors may influence the result. This experimental design allows to investigate the influences of all experimental variables, and interaction effects on the response.

Accordingly, for each experimental variant two independent variables for the preliminary spinning process plane have been adapted.

Independent variables chosen in the mathematical model are:

x_1 – fineness of delivered lap, Nm_d ;

x_2 – delivery velocity of the final opening machine, beating machine vd, m/min.

As dependent variable, response, of the yarns serves the irregularity, unevenness of the breaking load. This parameter is relevant because it encompasses the effects caused by several parameters like irregularity of linear density and torsion, the uneven placement of the compounds along the transversal and longitudinal yarn section.

2.2. Characteristics of processed raw materials

Aim of the study rely in the manufacturing of yarns with linear density of 25 tex, Nm 40, end use weft, from 100% cotton and cotton blended with chemical fibres. For this purpose a blend composed of 50% cotton and 50% polyester was selected. For the 100% cotton yarns the blending recipe presented in table 1, and for the blended yarns composed of 50% cotton+50% polyester chosen blending recipe is presented in table 2 [7].

Table 1. Recipe for blending cotton varieties, 100% cotton.

Linear density and destination	Variety	Blended fibre ratio (%)	Specific consumption
Tt = 20 ÷ 25 tex	M II	60	1.073
warp + weft	M III	40	1.088

Table 2. Recipe for blending 50% cotton+50% polyester.

Linear density and destination	Variety	Blended fibre ratio (%)	Specific consumption
All assortments	Cotton M II	50	1.073
warp + weft	Polyester	50	1.025

The properties of the raw materials involved in the study are given in table 3. Following notations were used: comp A - soviet cotton M II variety I; comp B - Soviet cotton M III variety II; comp C - American cotton M II SM ; comp D - polyester 1,5/38 [8, 9].

Table 3. The properties of the raw materials.

Properties	comp A	comp B	comp C	comp D
Linear density, Tt, mtex	181	192	197	166
Linear density, Td, den	-	-	-	1.5
Variation coefficient of linear density, %	-	-	-	5.3
Fiber fineness, Nm	5520	5200	5080	-
Micronaire index	4.6	4.8	5	-
Middle length, mm	-	-	-	38.1
Spinner length, mm	31	29.1	30.2	-
Breaking load (individual), cN	3.2	3.5	3.4	7.4
Variation coefficient of breaking load, %	-	-	-	17.3
Tenacity, cN/dtex	1.76	1.82	1.72	4.45
Specific strength Pressley, lb/in ²	79.8	80	76.5	-
Maturity	84	80	80	-
Impurities (manual), %	2.7	2.8	2.3	-
Fibre content < 14 mm, %	18	19	13	-
Fibre content < 10 mm, %	10	8	8	-
Lubricants, %	-	-	-	0.31
Bond fibres, %	-	-	-	0.004
Unstretched fibres, fb/100g	-	-	-	0.0002
Fibres with multiple length, %	-	-	-	0.002

2.3. Experimental possibilities

The technological flowcharts adopted for yarns manufacturing are presented in figures 1 and 2, where B – blow room, C, C1, C2 – cards, LI – the first draw frame, LII – the second draw frame, FM – medium roving frame, MFI – ring spinning machine, [7].



Figure 1. Technological flowchart for processing of cotton blend.

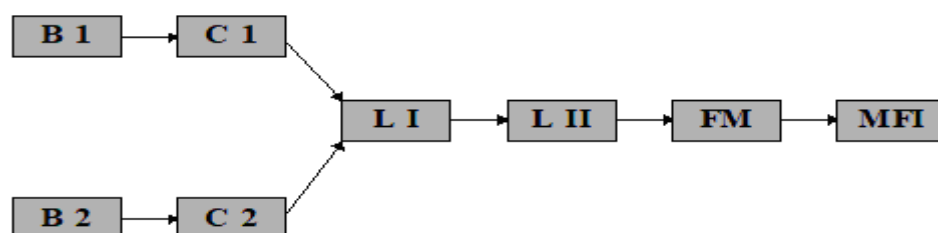


Figure 2. Technological flowchart for processing of cotton/PES blend.

The preliminary processing of cotton in the blow room was performed on a Trützschler line consisted of the following machines: 3+1 hopper feeding for bale breaker; collecting conveyor belt; axial cleaner; step cleaner; double horizontal opening, only the first opening module was used, and final opening machine.

The processing of polyester was carried out on a Textima line composed of the following machines: 3+1 hopper feeding for bale breaker; collecting conveyor belt; fine compound breaker; final opening machine, beating machine.

For the yarns of 50% cotton + 50% polyester, the blending was accomplished on the first passage on the draw frame.

For the cotton blend six experimental variants have been accomplished, according to the steps number of the technological flowchart. In case of the second blend, the experimental parts envisaged only the beating machine and the card for the processing of PES fibres along with the machines from the draw frame first passage till the ring frame, because the processing refers to a 50% cotton + 50% polyester blend. The operations steps and machines specific for cotton have been already analysed in case of the first blend [10]

The parameters applied for the preliminary spinning process plane used in the factories are comprised in tables 4 and table 5 for 100% cotton yarn and for the blended yarn 50% cotton +50% polyester respectively (contraction coefficient, $c_s = 0,95$ and false draft $L_f = 1,02$) [11].

Table 4. Preliminary spinning process plane, for cotton blend.

Machine	T _{td} tex	L _R	D	αt	T Twist /m	vd m/min	n rot/min	Pt kg/h.u
B	450x10 ³	4	-	-	-	8	-	218.2
C	4166	109	1	-	-	-	20	16
L I	4166	6	6	-	-	200	-	50
L II	4166	6	6	-	-	200	-	50
FM	625	6.66	1	948	37.9	-	680	0.66
MFI	25 B	25	1	4045	809.5	-	9000	0.017

Table 5. Preliminary spinning process plane, for cotton blend.

Machine	Comp	T _{td} tex	L _R	D	αt	T Twist /m	vd m/min	n rot/min	Pt kg/h u
Blow	Co	450x10 ³	4	-	-	-	8	-	218.2
room	PES	400x10 ³	5.7	-	-	-	6	-	144
Card	Co	4166	109	1	-	-	-	20	16
	PES	4166	96	1	-	-	-	18	14.4
Draw frame L I		4166	6	6	-	-	200	-	50
Draw frame L II		4166	6	6	-	-	200	-	50
Roving frame		625	6.66	1	821	32.9	-	680	0.76
Spinning machine		25 B	25	1	3792	759	-	9000	0.019

Experiments started with the beating machine maintaining the common adjustments of the other machines. The results of laboratory analysis for the produced yarns are mentioned in test reports. Based on the experimental values, adjustments accomplished for the beating machine aimed to achieve the smallest value for the irregularity of the breaking load. Further, the experimental part considered the card.

The pattern for the experiment was also preserved in this case, for all machines placed after the card in the flow chart (common adjustments were maintained). In this case too, the adjustments carried out follow to obtain yarns with the minimum value for the irregularity of the breaking load. The experiment moves towards the draft passage I. Actually the trials were conducted in the same mode for all machines from the flowchart.

3. Results and discussion

3.1. Experiments for the 100% cotton yarns

The coded levels and corresponding actual values of the two variables and their influence exerted upon the irregularity of the breaking load, comprised in the experimental matrix are given in table 6. Based on the experimental programme the coefficients of regression equation are as follows [12]

$$y = 14,1235 - 0,0362 \cdot x_1 + 0,1612 \cdot x_2 + 0,025 \cdot x_1 \cdot x_2 + 0,6689 \cdot x_1^2 - 0,0308 \cdot x_2^2 \quad (1)$$

The significance of the coefficients was tested with the T test and the suitability with the Student test [13] [102]. Hence, the b_{22} si b_{12} coefficients are insignificant, thus the equatio (1) becomes:

$$y = 14,1235 - 0,0362 \cdot x_1 + 0,1612 \cdot x_2 + 0,6689 \cdot x_1^2 \quad (2)$$

Table 6. Experimental matrix.

Nr. exp	Independent variables				Dependent variable		
	$x_1 \rightarrow$ cod	Nmd real	$x_2 \rightarrow$ vd (m/min) cod	real	y_{mas} (%)	y_{calc} (%)	Δy (%)
1	-1	0.00214	-1	4.58	14.7	14.6793	0.14
2	1	0.00285	-1	4.58	15	14.6069	2.62
3	-1	0.00214	1	7.41	14.8	15.0018	1.36
4	1	0.00285	1	7.41	15.2	14.9293	1.78
5	-1,414	0.002	0	6	15.7	15.5359	1.04
6	1,414	0.003	0	6	15	15.4334	2.88
7	0	0.0025	-1,414	4	13.6	13.8956	2.17
8	0	0.0025	1,414	8	14.3	14.3515	0.36
9	0	0.0025	0	6	14.1	14.1235	0.16
10	0	0.0025	0	6	14.2	14.1235	0.53
11	0	0.0025	0	6	14.1	14.1235	0.16
12	0	0.0025	0	6	14.1	14.1235	0.16
13	0	0.0025	0	6	14.1	14.1235	0.16

Calculus regarding the appropriateness of the applied mathematical model using the statistic method Fisher-Snedecor reveal the fact that the model represent the real shaped process, corresponding to a probability of de 95%. This assumption is supported also by the method applied to calculate the deviation based on the difference between the measured and calculated irregularity by means of the model. The deviation value of 2.88% proved the ability to describe, the process with a probability of de 95%.

By analysing the numerical coefficients of mathematical model in equation (2) a different influence of the two independent variables can be noticed because the delivery speed (x_2) exert an influence of 77,5% greater compared to the variable x_1 . Their influence upon the variation of the dependent variable y measured (response) by the changes of b_0 , in case of changes with one unit for one of the parameters is reduced, namely 0.2% for the lap fineness and 1,12% for speed delivery. This illustrate that the changes of the dependent variable occurs slowly due to the variation of the two independent parameters, thus the result is influenced by other factors too. Hence, the speed delivery exert an extend influence compared to that of the lap fineness.

The greater the speed delivery of the beating machine, the greater the irregularity of the breaking load of the yarns.

The same assumption is valid for the linear density of the lap: the bigger the thickness of the laps, due to difficulties in opening, the more significant is the irregularity of the lumps and implicitly of the produced yarns.

The analysis of the sign for the coefficients corresponding to the linear form of the two independent variables reveals that a reduction in irregularity of the breaking load can be achieved by:

- a crossed variation of the two parameters- x_1 vary towards the superior limit while x_2 towards the inferior limit of the experimental region
- or $x_1 = 0$ and variation of x_2 towards the inferior limit.

The greater the fineness of the laps, the draw in (open) is easier because the lumps propeled on the surface of the sieve drum are more even from dimensional and mass point of view. Thus the defibering is more effective till the complete opening at the cards.

The numerical values of the quadratic coefficients express the acceleration of the process. Along with the two parameters involved in the study, there are other factors of influence like: the gauge between the working parts, intensity of opening intensity of the technological air stream, pressure upon the feeding cylinder and the pressure exert on the lap in the region of the pressure calender.

Based on the insignificant result for the b_{12} coefficient, the interaction between the input variables produces a small influence.

By means of the experimental programme the graphical representation of the regression equation for each case was accomplished. The curves of constant level represent the plane projection of the section for $y=\text{const.}$ corresponding to the surface of the mathematical model, relation (2), which is an elliptic paraboloid. The analysis of the curves of levels represented in figure 3 lead to the conclusion that the achievement of the optimal values is excluded due to technological reasons. From the multitude of pairs of values comprised in quadrants I and II, only those from the quadrants II and IV are taken into consideration.

The acceptance of the values from quadrant I would lead to superior values of the dependent variables which in turns means low quality of the yarns.

The values from the quadrant II, with negative cod values for variable x_1 and positive values for variable x_2 lead also to superior values of the irregularity of the breaking load.

The minimum value of the dependent variable corresponding to the pair of cod values

($x_1=-0.0216$; $x_2=2.6044$) is situated outside the technological area.

Under these circumstances, an interesting value for the irregularity of the breaking load is the minimum value for the pair of cod values ($x_1=0$; $x_2=-1.414$), corresponding to the pair of parameters ($N_{md} = 0.0025$; $v_d = 4$ m/min).

Actually the delivery speed is very low which means a low productivity and an imbalance in production capacities.

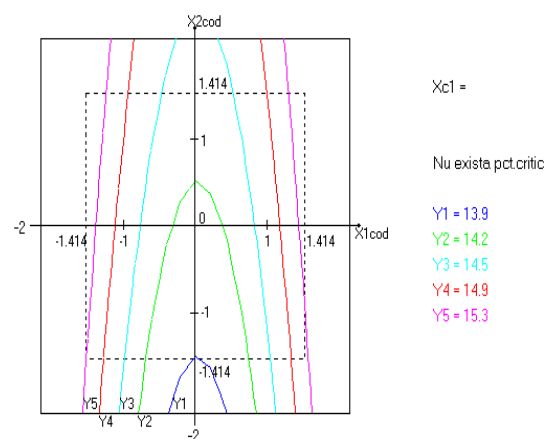


Figure 3. Influence of the lap fineness x_1 and delivery velocity x_2 , on the irregularity of the breaking load.

It is considered that the minimum value of the irregularity of the breaking load can be attained adjusting the process parameters for the pair of cod values ($x_1=0$; $x_2=-1.414$), equivalent to the pair of natural values ($x_1 = 0.0025$; $x_2 = 4$ m/min).

Therefore, the technological parameters were set according to this pair of values. Under this circumstances the value obtained for the dependent variable based on laboratory analysis was 13,2%. Compared to the value resulted by the application of the proposed mathematical model, this measured value present a deviation with 7.8 %. Thus, the optimization process was successful.

3.2. Experiments for the cotton/polyester yarns

The coded levels and corresponding actual values of the two variables and their influence upon the irregularity of the breaking load, comprised in the experimental matrix are given in table 7 [13]

Table 7. Experimental matrix.

Nr. exp	Independent variables				Dependent variable		A (%)
	$x_1 \rightarrow \text{Nmd}$		$x_2 \rightarrow \text{vd (m/min)}$		y_{mas} (%)	y_{calc} (%)	
	cod	real	cod	real			
1	-1	0.00214	-1	4.58	14	13.8910	0.77
2	1	0.00285	-1	4.58	14.1	14.3298	1.62
3	-1	0.00214	1	7.41	14.4	13.8910	3.53
4	1	0.00285	1	7.41	14.5	14.3298	1.17
5	-1.414	0.002	0	6	13.6	13.9747	2.75
6	1.414	0.003	0	6	14.7	14.5952	0.71
7	0	0.0025	-1.414	4	13.5	13.9351	3.22
8	0	0.0025	1.414	8	14.1	13.9351	1.16
9	0	0.0025	0	6	13.3	12.9634	2.53
10	0	0.0025	0	6	12.9	12.9634	0.49
11	0	0.0025	0	6	12.7	12.9634	2.07
12	0	0.0025	0	6	13.2	12.9634	1.79
13	0	0.0025	0	6	12.7	12.9634	2.07

Based on the experimental programme the coefficients of regression equation are as follows

$$y = 12,9634 + 0,2194 \cdot x_1 + 0,2061 \cdot x_2 + 0,6497 \cdot x_1^2 + 0,4747 \cdot x_2^2 \quad (3)$$

The T and Student test were applied to analyse the significance and suitability of the coefficients. The result confirmed the significance of all coefficients.

The appropriateness of the applied mathematical model was verified by means of the statistic method Fisher-Snedecor. According to the results (a probability of 95%) the model represents the real shaped process. This supposition is sustained also by deviation value based on the difference between the measured and calculated irregularity. The deviation value of 3.53 % proved the ability to describe the process with a probability of de 95%.

The analysis of the regression equation (3) reveals a similar influence exerts by the two parameters considered as independent variables on the dependent variable. However, a greater influence on the irregularity of the breaking load can be ascribed to the first parameter (lap fineness) because coefficient b_1 exceed with 6% the coefficient b_2 . Thus, an increase with one unit of the lap fineness determines a extend variation velocity of the dependent variable comparative to the delivery speed.

Their influence on the variation of the dependent variable (response), measured through the change of coefficient b_0 , in case of modification with one unit for one of these two parameters, is small: 1.66% for lap fineness and 1.56% for the delivery speed.

This aspect reveals that the changes of the dependent variable (response) occurs slowly due to the variation of the two independent parameters, thus the result is influenced by other factors, too. Because the discussed terms have the same sign, the minimization of the response occurs through a reduction of these parameters.

The numerical values of the quadratic coefficients describe the acceleration of the process. Along with the two parameters involved in the study, there are other factors of influence like: the gauge

between the working parts, intensity of opening, intensity of the technological air stream, pressure upon the feeding cylinder and the pressure exert on the lap in the region of the pressure calender.

The quadratic form of both parameters leads to the assumption that the model describes a well defined surface. Besides, the numerical values of the quadratic coefficients, which measure the acceleration of the process, having different values and additive signs, indicate a slow development of the minimization process. Comparing these coefficients, the influence caused by the parameter x_1 surpasses with 26.9% that of the parameter x_2 .

The analysis of the curves of levels, figure 4, reveals that in the frame of the experimental area, the response outlines consist of a family of ellipses obtained by the division of the elliptic paraboloid with planes of $y = \text{const}$.

The minimum values of the irregularity of the breaking load for the produced yarns can be attained with the pair of values contained in quadrant III. The minimum point 12.94 % is in this quadrant and corresponds to the pair of cod values ($x_1 = -0.16$; $x_2 = 0$) and real values ($T_t = 408 \text{ ktex}$; $vd = 6 \text{ m/min}$).

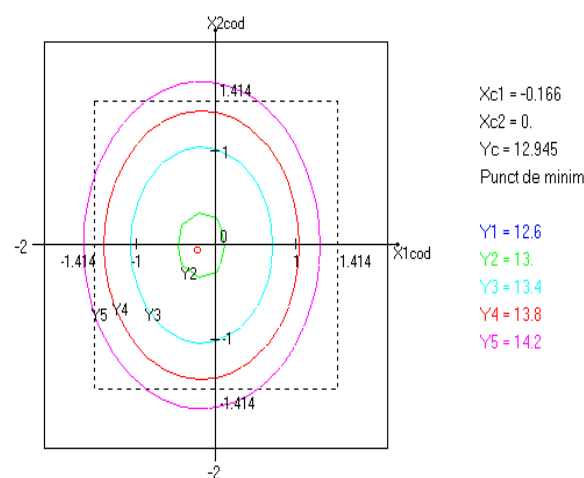


Figure 4. Influence of the lap fineness x_1 and delivery velocity x_2 , on the irregularity of the breaking load.

The selection of small values for both independent variables conducts, theoretically to low values of the dependent variables. In turns, from technological point of view this means a decrease in the theoretic capacities, production due to a difficult development of the opening at the final opening machine and an accentuated loading with electrostatic charges. This facilitates the winding at the card and on the cylinders belonging to the rolling mill until the spinning machines.

It is considered that low values for the irregularity of the breaking load can be expected with the following pairs of code values, as presented in table 8.

Table 8. Result of dependent and independent variables obtained by the mathematical model.

Code values		Dependent variable	Real values		Dependent variable
x_1 Nmd	x_2 vd (m/min)	y (%)	x_1 Nmd	x_2 vd (m/min)	y (%)
0	0	12.0	0.0025	6.0	12.96
0	0	12.3	0.0023	6.0	13.0
0	-0.5	12.2	0.0025	5.3	13.08

Therefore, the technological parameters were adjusted according to these pairs of values. The measured results obtained for the dependent variable are comprised in table 8.

Compared to the values obtained by the mathematical model 12.96%, 13% and 13.08%, the deviation is below 10% (7.4%, 5.3% and 6.7%) which highlights a successfully optimization process.

4. Conclusion

In this study mathematical models for the technological steps for yarn production were proposed and applied. Based on mathematical and technological analysis, the optimal values regarding the parameters for the beating machine, card, drawing frame I and II, ring frame and rotor spinning could be established.

The optimization process comprised all steps of the technological flowchart for the 100% cotton yarn and blends of cotton with chemical fibres for both, conventional and unconventional spinning procedure.

The results offer information about the physical and moral abrasion of the machines. Thus, to avoid physical machine abrasion and to enhance the quality of the intermediate products and yarns, a reduction in working Thought, reduction in working parameters for definite technological steps can lead to narrow places. But, taking into account that the most spinning mills are working at a capacity below 50%, machines are available to avoid this situation.

Waste due to an increase in energetic consumption can be compensate by the price difference between the yarns with quality A and quality B.

Furthermore, a raise in the number of operating machines to achieve the same production does not involve an increase in working personnel because through a reduction of the working parameters a growth of the working zone becomes possible.

5. References

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